Geologic base simplified from Winkler (1992) Base from U.S. Geological Survey, 1962 Limited revision 1985 Manuscript approved for publication March 9, 1993 **EXPLANATION** SOUTH OF BORDER RANGES FAULT Limestone and marble (Late Triassic?)—Massive to poorly bedded Valdez Group (Late Cretaceous)—Complexly deformed, foliated Bedded rocks Area containing gold in heavy-mineral-concentrate samplesflyschoid metasedimentary rocks including metasandstone, limestone interbedded with rocks mapped as part of Talkeetna Small number is the number of samples that contain gold as Formation and as roof pendants metasiltstone, argillite, slate, and phyllite and rare beds of pebbly

determined by visual inspection and (or) emission spectroscopy. See text for descriptions of areas Eocene and Paleocene TERTIARY **CORRELATION OF MAP UNITS** Kv Late Cretaceous **CRETACEOUS** ALL AREAS **MESOZOIC** Unconsolidated deposits Intrusive rocks Tmp QUATERNARY Oligocene or Eocene TERTIARY NORTH OF BORDER RANGES FAULT Tfp Bedded rocks DESCRIPTION OF MAP UNITS **ALL AREAS** Tc Tar Eocene and Paleocene Unconsolidated deposits Late and Early Cretaceous **CRETACEOUS** Glaciers and superglacial moraine (Holocene) Surficial deposits (Quaternary)—Undivided glacial, alluvial, colluvial, **JURASSIC** Late and Middle Jurassic and lacustrine deposits, rock glaciers, and landslides JÆt TRIASSIC(?) Early Jurassic and Late Triassic(?) NORTH OF BORDER RANGES FAULT Te1 Bedded rocks Tyonek Formation (Miocene)—Carbonaceous sandstone, siltstone, shale, and claystone Intrusive rocks Volcanic rocks (Miocene? to Paleocene)—Bimodal volcanic flows, tuffs, and hypabyssal intrusions and minor intercalated Ti Eocene. sedimentary rocks **TERTIARY** TKi Sedimentary rocks, undivided (Oligocene and Eocene)—Tsadaka Paleocene and Late Cretaceous Formation (Oligocene) and Wishbone Formation (Eocene). Fluviatile conglomerate, sandstone, siltstone, and claystone, with Kw local partings of ash Late Cretaceous Kum Chickaloon Formation (Eocene and Paleocene)—Fluviatile and alluvial **CRETACEOUS** carbonaceous mudstone, siltstone, conglomeratic sandstone, and Kt conglomerate; middle and upper parts contain numerous beds of Early Cretaceous bituminous coal Jtr Arkose Ridge Formation (Eocene and Paleocene)—Fluviatile and Late Jurassic alluvial feldspathic, biotitic, and carbonaceous sandstone, conglomerate, siltstone, and shale Jgd Jqd **JURASSIC** Middle Jurassic Matanuska Formation (Late and Early Cretaceous)—Marine shale, siltstone, sandstone, and subordinate conglomerate Jmip / Jg / Jum Middle and Early Jurassic Sedimentary rocks, undividied (Late and Middle Jurassic)—Naknek Formation (Late Jurassic), Chinitna Formation (Middle Jurassic), and Tuxedni Group (Middle Jurassic), undivided-Metamorphic rocks Marine siltstone, shale, sandstone, and conglomerate Jps JURASSIC(?) Talkeetna Formation (Early Jurassic and Late Triassic?)—Mafic to JURASSIC intermediate flows, flow breccia, tuff, shallow sills, and J₽₂m TO MIDDLE agglomerate and subordinate interbedded sandstone, conglomerate,

PALEOZOIC(?)

and marine siltstone and shale

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Intrusive rocks Hypabyssal intrusions (Eocene)—Stocks, dikes, and sills of mafic, intermediate, and felsic igneous rocks Intrusive rocks, undivided (Paleocene and Late Cretaceous)— Composite epizonal or mesozonal pluton consisting principally of granite and tonalite, but also containing granodiorite, quartz monzonite, and quartz diorite. Age is Late Cretaceous and early Willow Creek pluton (Late Cretaceous)—Pervasively altered, zoned pluton consisting of a granodiorite, quartz monzodiorite, and quartz monzonite core and a quartz diorite and tonalite margin Serpentinized ultramafic rocks (Late Cretaceous)—Small, discordant bodies of serpentinized ultramafic rocks Leucotonalite and trondhjemite (Early Cretaceous)—Plugs and elongate, sill-like bodies of leucocratic plutonic rocks Trondhjemite (Late Jurassic)—Discordant, faintly foliated, leucocratic, epizonal plutons that contain large screens of quartz diorite and Granodiorite (Middle Jurassic)—Large, epizonal pluton and satellitic stocks of granodiorite and some tonalite and quartz diorite Quartz diorite (Middle Jurassic)—Large, discordant, sheared and altered, epizonal pluton consisting predominantly of mediumgrained quartz diorite and some diorite and tonalite Mafic and intermediate plutonic rocks (Middle and Early Jurassic)-Complexly intermixed series of mafic to intermediate, coarse- to fine-grained plutonic rocks consisting of sheared and altered gabbronorite, hornblende gabbro, diorite, quartz diorite, and Gabbronorite (Middle and Early Jurassic)—Fine- to coarse-grained gabbroic rocks; intensely sheared and altered locally with minor amounts of serpentinized ultramafic rocks Ultramafic and mafic rocks (Middle and Early Jurassic)—Cumulate dunite, pyroxenite, peridotite, and gabbronorite forming two large fault-bounded sequences in the northern Chugach Mountains. Composed of the informally named Eklutna complex of Clark and Greenwood (1972) and the Wolverine Complex of Carden and Decker (1977) Metamorphic rocks Pelitic schist (Jurassic?)—Homogenous pelitic schist known to exist only in the Willow Creek mining district of the southwestern Talkeetna Mountains Metamorphic rocks (Jurassic to middle Paleozoic?)—Intricately intermixed amphibolite, foliated quartz diorite, and lesser trondhjemite in the southern Talkeetna Mountains and diverse metasedimentary and metavolcanic rocks cropping out near plutonic rocks along northern flank of the Chugach Mountains SOUTH OF BORDER RANGES FAULT

Bedded rocks

breccia, and tuff

Orca Group (Eocene and Paleocene)—Complexly deformed flysch and

tholeiitic volcanic rocks consisting of sandstone, siltstone,

mudstone, conglomerate and interbedded basaltic flows, pillow

argillite and metasandstone and minor interbedded mafic metatuff ugh Complex (Mesozoic)—Strongly deformed, melange-like assemblage between the Eagle River and Border Ranges faults consists of argillite with wispy lenses of green chloritized tuff, thinly bedded siliceous argillite and argillaceous chert. Contains enclosed tracts of aligned phacoids of diverse extraformational rock types including schist, amphibolite, marble, sandstone, conglomerate, diorite, gabbro, serpentinized ultramafic rocks, and mafic volcanic rocks Intrusive rocks Miners Bay pluton (Oligocene)—Composite pluton consisting of texturally variable gabbroic and dioritic rocks intruded by slightly younger, altered, medium-grained biotite granite Granite and granodiorite (Oligocene or Eocene)—Small plutons and numerous leucocratic dikes that have low color indices (ranging from 5 to 20) and abundant alkali-feldspar Felsic plutons (Eocene)—Altered, fine-grained, porphyritic dacite and rhyolite dikes, sills, and small stocks occurring widely south of the Border Ranges fault Contact—Approximately located; dotted where concealed; queried where — High-angle fault—Approximately located; dotted where concealed Thrust fault—Approximately located; dotted where concealed; sawteeth on upper plate INTRODUCTION The distribution of gold in the Anchorage 1° by 3° quadrangle is evaluated here as part of the Alaska Mineral Resource Assessment Program (AMRAP). This report is part of a series of publications prepared by the U.S. Geological Survey (USGS) to provide the public with information on the mineral resources of Alaska. The mineral-resource information serves as potential input for land-use planning and minerals-policy development, as a guide to minerals exploration, and to add to the geologic and geochemical knowledge of the area. Companion reports (Arbogast and others, 1987; Madden and others, 1988; Madden, 1991a, 1991b; Tripp and Madden, 1991) present geochemical data and map distributions of various metals and ore-related minerals in stream-sediment and heavy-mineral concentrate samples. The geologic base map was simplified from Winkler (1992).

To obtain

centimeters (cm)

kilometers (km)

meters (m)

0.3048

1.609

feet (ft)

miles (mi)

Willow Creek, just below the mouth of Grubstake Gulch. 15 Nautical Miles CONTOUR INTERVAL 200 FEET NATIONAL GEODETIC VERTICAL DATUM OF 1929 BATHYMETRIC CONTOUR INTERVAL 10 METERS TO MAXIMUM DEPTH SUPPLEMENTED BY 5 METER INTERVALS

DATUM IS MEAN LOWER LOW WATER

THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER

GEOCHEMICAL MAP SHOWING THE DISTRIBUTION OF GOLD IN THE ANCHORAGE 1° X 3° QUADRANGLE, ALASKA

Dawn J. Madden-McGuire and Richard B. Tripp

The sources of placer gold in the Willow Creek mining district are gold-enriched veins, hosted in a unit of schist and in a pluton. The most productive lode veins are hosted in a 79-72-Ma, propylitically altered pluton (called the Willow Creek pluton; Winkler, 1992). The Late Cretaceous Willow Creek pluton is zoned, and it has an outer margin of hornblende quartz diorite and lesser hornblende tonalite and a core of homblende-biotite granodiorite and lesser biotite-quartz monzonite (Winkler, 1992). Mineralized veins are near the contact between the zoned pluton and the pelitic schist the contact is interpreted to be a fault, which may have served as a conduit for oreforming fluids at 66 Ma and 57-55 Ma (Madden-McGuire and others, 1989). Adjacent Late Cretaceous and early Paleocene granite (67 and 65 Ma) to the northwest is barren of gold-bearing quartz veins and might have formed after the main period of mineralization.

The Anchorage quadrangle encompasses about 18,000 km<sup>2</sup> (square kilometers) of

south-central Alaska, bounded by the 61° and 62° parallels and the 147° and 150°

meridians. The quadrangle includes, from north to south, the southern Talkeetna

highest point in the quadrangle is Mount Marcus Baker (4,016 m) in the Chugach

quadrangle) flows southward and enters Knik Arm to the west of the Anchorage

The Municipality is bounded by lower Knik Arm, lower Turnagain Arm, and the

In the southwestern part of the Anchorage quadrangle, the lowland coastal area

(about 5,200 km<sup>2</sup>) of the Municipality of Anchorage projects into the head of Cook Inlet.

**GEOLOGIC SETTING** 

The Anchorage 1° x 3° quadrangle is underlain by three lithotectonic terranes

(Silberling and Jones, 1984), which are distinctive fault-bounded assemblages of rock

energy resources (fig. 1). The Peninsular terrane underlies the Talkeetna Mountains,

rugged crest of the Chugach Mountains; and the Prince William terrane underlies the

extreme southeastern part of the quadrangle in Prince William Sound (Winkler, 1992;

Nilsen and Zuffa, 1982). The terranes were accreted successively to southern Alaska

from Middle Jurassic to middle Eocene time (Plafker and others, 1977, 1989; Csejtey

The Peninsular terrane in the Anchorage quadrangle is bounded on its south side by

the Border Ranges fault system (Winkler, 1992). The terrane consists of Triassic(?) to

rocks, and Paleozoic(?) to Jurassic metamorphic rocks (Csejtey and others, 1978; Pavlis,

younger than mid-Cretaceous overlap the accretionary assemblages and cover much of

Tertiary bedded volcanic and sedimentary rocks, Early Jurassic to Tertiary intrusive

1983; Winkler, 1992). Rocks older than mid-Cretaceous are allochthonous; rocks

and others, 1978; Tysdal and Case, 1979; Burns and others, 1991).

the western part of the quadrangle.

Peninsular terrane

Burns and others, 1991).

along the Eagle River thrust fault.

and others, 1989; Burns and others, 1991).

of Oligocene age (Nelson and others, 1985).

samples collected from streams.

Figure 1. Generalized lithotectonic terranes and major fault

boundaries in the Anchorage 1°×3° quadrangle.

South of the Peninsular terrane is the Chugach terrane, which is bounded by the

Border Ranges fault system on the north and by the Contact fault system on the south.

In the Anchorage quadrangle, the Chugach terrane consists of a landward subduction

assemblage of melange and broken formation of the McHugh Complex and seaward

trench-fill and trench-slope deposits of the Valdez Group (Plafker and others, 1977;

Exposures of the Mesozoic McHugh Complex form a discontinuous band along the

south side of the Border Ranges fault system, within the upper plate of the Eagle River

mafic metavolcanic and metaclastic rocks, bedded chert, and minor lenses of limestone

and ultramafic rocks in an argillaceous matrix. These blocks were chaotically faulted

together, metamorphosed to prehnite-pumpellyite facies, and accreted between Middle

Jurassic and mid-Cretaceous time (Clark, 1973; Winkler and others, 1981; Plafker and

The Upper Cretaceous Valdez Group consists of metamorphosed, rhythmically

mafic tuff. The sedimentary rocks are interpreted as trench-fill and trench-slope deposits

(Burns and others, 1991). The thickness of the metamorphosed and deformed Valdez

Group is unknown in the Chugach Mountains. To the southeast, on Sanak, Shumagin,

Afognak, and Kodiak Islands, correlative strata have been estimated to be 3-5 km thick

(Moore, 1973; Nilsen and Moore, 1979). The age of the Valdez Group is Campanian(?)

and Maestrichtian (Jones and Clark, 1973). The Valdez Group was accreted between

regionally metamorphosed during a thermal event that culminated in early middle

latest Cretaceous and early Paleocene time, intruded by widespread felsic plutons, and

Eocene time (48-52 Ma; Hudson and Plafker, 1982; Sisson and Hollister, 1988; Plafker

William terrane, which consists of 6-10 km of interbedded graywacke, siltstone, shale,

conglomerate, and minor greenstone that lithologically resemble rocks of the Valdez

separated by the Contact fault, a northward-dipping thrust. Between Columbia Glacier

and Lyon (1973) discussed the stratigraphy and tectonics of the region. The inlet is

underlain by more than 12,000 m of Mesozoic marine sedimentary and volcanic rocks

and as much as 9,000 m of Tertiary estuarine and nonmarine rocks that record three

nonmarine sedimentation. Cycles of deposition were interrupted by times of orogeny

and corresponding (related) shifts in the depositional center of the proto-Cook Inlet

basin. The Tertiary strata contain most of the coal deposits in the Anchorage quadrangle

In 1982-85, in order to do a regional geochemical and mineralogical study of the

Anchorage quadrangle, the USGS collected samples of heavy-mineral concentrate from

stream sediment to supplement the existing data available in from Clark and Bartsch

(1971a, 1971b), Clark and Yount (1972), Clark, Yount, and Bartsch (1976), and Zinkl

and others (1981). USGS personnel primarily sampled first-order (unbranched) and

1:63,360-scale topographic maps. In addition to sampling heavy-mineral concentrate

lateral moraines in areas of extensive glacial cover and treated them the same as the

of minus-80-mesh stream- and glacial-moraine sediment at 524 sites. In the Chugach

and Prince William terranes, the USGS collected the heavy-mineral fraction of stream

composite rock samples collected from nunataks for the purpose of concentrating the

heavy minerals. Collection from the nunataks expanded the area sampled for heavy-

Chugach Mountains, such as the snowfields above the Knik Glacier. The nunatak rocks

were coarsely pulverized in the laboratory with ceramic plates, panned, and then treated

The heavy-mineral concentrate samples were collected by scooping numerous grab

Heavy-mineral concentrate samples were air-dried and an electromagnet was used to

remove highly magnetic minerals such as magnetite and ilmenite. Following the first

magnetic separation, the less magnetic material was separated by flotation in bromoform

which has a specific gravity of 2.86, and the denser heavy-mineral fraction was extracted.

The heavy-mineral fraction then was separated into nonmagnetic and magnetic fractions

with a Franz Isodynamic Separator with a coil setting equivalent to 0.7 ampere and track

each sample was carefully examined for gold under a binocular microscope and analyzed

RESULTS

Gold

The map shows the distribution of sample localities in which gold was identified in

heavy-mineral concentrate by binocular microscope and (or) by analysis. The USGS

semi-quantitative, direct-current arc emission spectrographic method (Grimes and

collected 1,168 samples of heavy-mineral concentrate in the quadrangle; of these, 160

samples contain microscopically visible gold and 136 samples contain gold detected by a

Marranzino, 1968; Arbogast and others, 1987). The lower and upper detection limits for

Areas outlined on the map generally encompass all potential source areas for the

gold-bearing samples. The area boundaries generally correspond to ridge tops separating

drainage basins, and, in some places, to boundaries of geologic units favorable for gold.

Area 1—Gold from gold-bearing quartz-carbonate veins in the

Willow Creek gold-mining district

Area 1 is in the northwestern part of the quadrangle and includes the Willow Creek

gold-mining district. This area has a high potential for gold-bearing placers, particularly

in Willow Creek, Grubstake Gulch, and Wet Gulch. Placer gold has been mined since

Fishhook Creek, which proved to be uneconomical because of large boulders (Cobb,

1979). In 1990, the district supported several small placer operations, two on Willow

Creek and one on the Little Susitna River (Swainbank and others, 1991). USGS heavy-

mineral-concentrate samples contained gold from all the above-mentioned streams, plus

from Craigie Creek. During the early 1990's, placer gold was still being mined from

1897 from Willow Creek and Grubstake Gulch and briefly in 1906 from the lower part of

For example, the northern boundary of area 2B corresponds to the Eagle River fault,

settings equivalent to 5° forward slope and 10° side tilt. The nonmagnetic fraction of

samples along a 9-30-m length of active stream channel or across the entire width of an

active moraine. The grab samples were composited into a single 3-4-kg sample and

screened in the field using a 2.0-mm (10-mesh) stainless steel screen to remove the

coarse material. Then, the minus-2.0-mm material was panned to remove quartz,

and glacial-moraine sediment at 644 sites. Sixteen Chugach terrane samples were

mineral concentrate into the previously unsampled icefields and snowfields of the

the same way as the other heavy-mineral concentrate samples.

feldspar, organic material, and clay-size particles.

for gold using a semi-quantitative spectrographic method.

gold were 20 ppm (parts per million) and 1,000 ppm.

which is the northern contact of the Valdez Group.

second-order (below the junction of two first-order streams) streams as shown on USGS

from streams, USGS personnel also sampled heavy-mineral concentrate from medial and

In the Peninsular terrane, the USGS collected samples of the heavy-mineral fraction

Mesozoic cycles of marine sedimentation and two Tertiary cycles of estuarine and

and account for most of the oil and gas production in southern Alaska.

and Unakwik Inlet, the Valdez and Orca Groups are intruded by mafic to felsic plutons

In the western part of the Anchorage quadrangle is the Cook Inlet region. Kirschner

Group (Nelson and others, 1984). The Chugach and Prince William terranes are

Southeast of the Valdez Group is the Paleocene and Eocene Orca Group of the Prince

interbedded graywacke, siltstone, and argillite, some pebble conglomerate, and some

others, 1989; Burns and others, 1991). The McHugh Complex overlies the Valdez Group

thrust fault. The McHugh Complex contains Carboniferous to mid-Cretaceous blocks of

that differ from each other in stratigraphy, age, structural style, and types of mineral and

Matanuska Valley, and northern Chugach Mountains; the Chugach terrane underlies the

fiords and bays of the northwestern part of Prince William Sound.

Mountains, Matanuska River Valley, the heavily glaciated Chugach Mountains, and

Topographic relief in the Anchorage quadrangle exceeds 4,000 m (meters). The

Mountains. The top of Mount Marcus Baker is only 19 km from coastal fiords of Prince

The Matanuska, Knik, and Susitna Rivers form the major watershed to the north and

east of Anchorage. The Knik and Matanuska Rivers flow westward and converge as they enter Knik Arm, which is a branch of upper Cook Inlet. The Susitna River (west of the

> Less productive and less abundant gold-bearing veins are in a unit of pelitic schist adjacent to the Willow Creek pluton. However, these less productive veins have yielded much of the placer gold in the district. In 1897, the first placer claims were staked on Willow Creek, at the mouth of Grubstake Gulch, which drains the area exposing the schist. In 1899, two more claims were staked on lower Grubstake Gulch. A hydraulic plant was installed and placer production peaked in 1904 and 1905. In 1990, two small placer mines operated on Willow Creek (Swainbank and others, 1991). In the schist, gold occurs in shear zones of comminuted schist, together with calcite, quartz, albite, chlorite, muscovite, pyrite, marcasite, arsenopyrite, chalcopyrite, sphalerite, and very fine grained cerrusite or anglesite. Alteration selvages surrounding mineralized veins in the schist are oxidized because the mineralized shear zones and faults are relatively

permeable to ground water.

#### Areas labeled 2, 2A, and 2B—Gold derived from gold-bearing quartz-carbonate veins in the Valdez Group of the Chugach terrane

In the area underlain by the Valdez Group, placer mining has been carried out mostly in the Girdwood gold mining district (area 2A) and in Metal Creek (area 2B, western part). Many other areas are labeled 2 on the map. These areas enclose additional drainages within the Valdez Group, which contain gold in heavy-mineral-concentrate samples, as determined by emission spectrography and (or) by microscopic inspection. Numerous gold-bearing areas are outlined on the map, because the entire Valdez Group within the Anchorage quadrangle is considered permissive for gold- and silverbearing quartz veins (Madden-McGuire and Winkler, in press). Areas where gold is in heavy-mineral-concentrate samples are more likely to contain gold-quartz veins, as indicated by the example of the Girdwood mining district discussed below. The Valdez Group is bounded by the Border Ranges and Eagle River faults to the north, and it extends to the quadrangle boundaries to the south and east.

Area 2A includes the Girdwood mining district. Within the district, gold was found in USGS heavy-mineral-concentrate samples from the upper parts of Crow Creek, Raven Creek, Bird Creek, North Fork of Ship Creek, and Glacier Creek. This area, particularly Crow Creek, has a high potential for placer gold. The deposits on Crow Creek were first claimed in 1895, were mined continuously until World War II (Cobb, 1979), and have been mined sporadically since then. Most of the mining has been done near the southern boundary of the Anchorage quadrangle. Nuggets commonly weigh 0.025-0.05 oz, but some weigh as much as 1 oz. The gold content of six samples of placer gold averaged 72 percent Au, 22 percent Ag, and the remainder base metals (Hoekzema, 1984). U.S.G.S. heavy-mineral concentrate samples from Crow Creek and from surrounding drainages contain anomalously high concentrations of gold (as well as Ag, As, and Sb; Madden, 1991a; Tripp and Madden, 1991). Crow Creek has been the largest producing placergold stream in the Kenai-Chugach Mountains, producing about 42,500 oz of relatively coarse gold (much of it >14 mesh) between 1898 and 1982 (Hoekzema, 1984; Jansons and others, 1984). Production was 400 oz between 1979 and 1983; recreational mining remains popular. The inferred placer gold reserve in Crow Creek, within and south of the Anchorage quadrangle, is estimated at >1,000,000 cubic yards of gold-bearing gravel (Jansons and others, 1984). Personnel from the U.S. Bureau of Mines have suggested that creeks other than Crow Creek may contain placer deposits that contain subeconomic

quantities of gold (Jansons and others, 1984). The sources for the placer gold in the Girdwood gold-mining district are lode deposits in which gold is concentrated in quartz-carbonate veins in shear zones and joints within metasedimentary rocks of the Valdez Group. Within the district, abandoned lode gold mines in upper Crow Creek produced 4,932 oz of gold from veins in the Monarch and Jewel mines, mostly between 1937 and 1942 (Cobb, 1979; Jansons and others,

Area 2B includes the Metal Creek drainage (in the western part). Placer gold was discovered in Metal Creek in about 1906 and mined sporadically for about 20 years in the early 1900's (Richter, 1967; Cobb, 1979). USGS heavy-mineral-concentrate samples from Metal Creek and four tributaries were enriched in Au; upper Cottonwood Canyon, he canyon north of Paradise Creek, and the first and third canyons south of Metal Cree Glacier contained gold in heavy-mineral concentrate. No placer-mining operations were seen in the early 1980's. Generally, in the Chugach terrane, gold-enriched quartz veins are concentrated in

areas underlain by metasedimentary rocks of the Valdez Group that have been regionally metamorphosed to medium greenschist facies (characterized by incipient growth of biotite in graywacke). Locally, gold-enriched quartz veins are in thermally metamorphosed rocks adjacent to plutons where the pressure and temperature (P-T) conditions were similar to those of medium-grade greenschist-facies metamorphism (Goldfarb and others, 1986). The vein-forming fluids in the Valdez Group were produced from metamorphic devolatilization during Tertiary regional metamorphism Vein emplacement followed hydraulic fracturing during uplift of the region (Goldfarb and others, 1986). Veins in the Valdez Group consist mostly of quartz, injected in multiple stages, and later calcite and ankerite with traces of gold and sulfide minerals. Arsenopyrite is the most abundant and earliest sulfide mineral to form, and it is followed by pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, and sparse stibnite (Goldfarb and

In area 2B, between the Marcus, Baker Glacier and the Matanuska River, on the south side of the Border Ranges fault system, many heavy-mineral-concentrate samples contained gold. The eastern part of this area exposes mineralized base-metal- and goldenriched quartz veins in altered, iron-stained metasedimentary rocks and plutonic (quartz diorite) intrusions (Richter, 1967: Madden and others, 1988). The veins contain as much as 0.25 ppm Au, 5 ppm Ag, 2,000 ppm As, 2,000 ppm Cu, and >2,000 ppm Zn (Madden and others, 1988). Gold-bearing heavy-mineral concentrate samples in the lower half of the Grasshopper Valley drainage also contain chalcopyrite (eight samples), sphalerite (three samples), galena (seven samples), and arsenopyrite (13 samples) (Tripp and Madden, 1991). Many heavy-mineral-concentrate samples collected throughout the eastern part of area 2B are enriched in Ag, As, and Sb. However, the fluvioglacial setting in the eastern part of this area is less favorable for the development of placer deposits than the more fluviatile settings of Metal Creek (in the western part of area 2B) and Crow Creek (area 2A). The occurrence of placer platinum in Metal Creek is disputable. Placer platinum was reported by Smith (1926) but not by Richter (1967).

# Areas labeled 3—Gold derived from the McHugh Complex

The McHugh Complex consists of metaclastic and metavolcanic rocks that have undergone weak regional metamorphism to prehnite-pumpellyite facies (Clark, 1973). Although the McHugh Complex has not proved to be a favorable host-rock unit for goldbearing veins in the Anchorage quadrangle (except locally in Peters Creek, as reported by Cobb, 1979), gold does occur in heavy-mineral concentrate samples in areas draining only the McHugh Complex. The exact sources for the gold are unknown. These areas that yielded gold are labeled 3 and are in the southwestern part of the quadrangle. They are Rabbit Creek drainage, upper Ship Creek, and upper Peters Creek. The area in upper Peters Creek exposes Eocene felsic intrusions within McHugh Complex, and some concentrate samples are enriched in Ag, As, Pb, and Zn in addition to Au; intrusions are not mapped in the other two drainage areas (Winkler, 1992), which contain only anomalously high concentrations of Au.

### Area labeled 4—Gold derived from the Orca Group Sedimentary rocks of the Orca Group generally lack gold-bearing quartz veins, but

one exposure of the Orca Group near the Columbia Glacier contributed gold to the heavy-mineral fraction of a glacial-moraine sediment sample. The exact source of the gold is unknown. Area 4, along the Contact fault, in the southeastern part of the quadrangle, contains this exposure.

### Areas labeled 5, 5A, 5B, and 5C-Gold derived from other, unknown sources in various units of the Peninsular terrane

In areas labeled 5 on the map, gold was found in heavy-mineral concentrate derived from (1) volcanic and sedimentary rocks of the Upper Triassic(?) and Lower Jurassic Talkeetna Formation, (2) Tertiary (Paleocene to Miocene?) volcanic and hypabyssal intrusive rocks and siliceous rhyolitic domes in the basal part, (3) Cretaceous and Tertiary sedimentary rocks, and (4) Jurassic plutonic rocks. In the Alfred Creek drainage, which is in the eastern part of area 5A in the

northeastern part of the quadrangle, placer gold was discovered in 1911 and has been mined sporadically since. Small-scale mining continued there at the time of these investigations (early 1980's). However, only a few USGS heavy-mineral-concentrate samples from Alfred Creek contain gold (only five samples from Alfred Creek and two tributaries out of a total of 28 samples from the drainage). One of the gold-bearing samples is from the placer gold area delineated by Cobb (1979); one sample is from an area several miles upstream near the northern boundary of the quadrangle; one is from nearby Flume Creek, a tributary of Alfred Creek; and two from an area several miles downstream from the placer-mining area. At the northeast end of the Alfred Creek drainage, near Table Mountain, placer gold was found in South Creek in 1913 and in Poorman Creek in 1914 (Cobb, 1979). However, USGS heavy-mineral-concentrate samples from near those areas lacked gold. Brooks (1925) and Cobb (1979) reported small quantities of platinum in the placers of the Alfred Creek drainage. The source of the platinum in uncertain. Perhaps it came from paleoplacer deposits in Jurassic sedimentary rocks in the Alfred Creek drainage. The drainage exposes mostly the Talkeetna Formation and Tuxedni Group to the north, separated from the Matanuska Formation to the south by the Caribou fault (Winkler, 1992).

In Caribou Creek, which is in the western part of area 5A, gold mining was reported in 1912 (Cobb. 1979), but there was no sign of operations during the early 1990's. Four out of eight USGS heavy-mineral-concentrate samples were enriched in Au in Caribou Creek. Caribou Creek exposes mostly the Matanuska Formation and Tertiary volcanic rocks north of the Caribou fault and the Tuxedni Group and Chinitna Formation south of

In Boulder Creek, area 5B, placer gold prospects were reported in and below the canyon, but there are no records of commercial production (Cobb, 1979), and there was no sign of operations during the early 1990's. Four out of sixteen USGS heavy-mineral concentrate samples contained gold in the drainage (some of these gold-bearing samples also were enriched in As and Ag). The two gold-bearing samples located highest in the drainage are between the Caribou Fault and Castle Mountain faults, in a faulted area, and the other two are in lowlands, south of the Castle Mountain fault. One of these samples is in the vicinity of Cobb's (1979) two placer-gold prospects, in the lower part of Boulder Creek. Platinum is included as a commodity for Boulder Creek placers according to J.Y. Foley of the U.S. Bureau of Mines (written commun., 1991). Boulder Creek exposes Tertiary volcanic rocks, the Tuxedni Group, and the Chinitna Formation in the northeast part; the Talkeetna Formation, intruded by felsic and intermediate Eocene hypabyssal rocks in the middle part; and the Chickaloon Formation, Wishbone Formation, and Tertiary volcanic rocks in the southwest

Mineralized rocks are exposed in area 5B on the north side of the middle part of Boulder Creek (Madden and others, 1988), where the Talkeetna Formation (and possibly adjacent units) is altered along fractures trending about N. 55° W. Rocks are locally silicified, brecciated, intruded by dikes, and contain visible pyrite. Altered rocks contain 0.1 ppm Au, 10 ppm Ag, and enrichments in base metals (as much as 2 percent Cu, 5,000 ppm Pb, >2,000 ppm Zn, and 3,000 ppm Ba; Madden and others, 1988) in nine grab samples. Newberry (1986) interpreted similar mineral occurrences in the Talkeetna Formation as being originally syngenetic and localized by structures. Although the volcanic and sedimentary rocks of the Talkeetna Formation are locally Au-enriched in the Anchorage and Valdez quadrangles, as described by Newberry (1986), they are not known to host any significant gold deposits. Samples taken directly downstream from these outcrops lack gold in heavy-mineral concentrate. Therefore, these outcrops probably did not contribute gold to the stream sediment in the Boulder Creek area (5B).

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The Boulder Creek area (5B) also exposes a felsic border phase of an Eocene hypabyssal intrusion along a fault on the southeast side of the creek (Madden and others, 1988). The margin of the intrusion contains disseminated sulfide minerals and 0.052 ppm Au, 500 ppm Ag, 500 ppm Cu, 2,000 ppm Pb, and 1,500 ppm Zn (Madden and others, 1988). One sample from an adjacent drainage to the east contains gold in heavymineral concentrate. The gold could have come from lithologically similar exposures of hypabyssal intrusive rocks on the south side of Boulder Creek. Tertiary felsic volcanic rocks to the north, in the Talkeetna Mountains quadrangle, contain gold and copper occurrences and yielded heavy-mineral panned concentrate enriched in Cu, Pb, As, Ag, veins. Singer and others (1978) therefore delineated part of the Talkeetna Mountains Gold-quartz veins in the zoned Willow Creek pluton are in shear zones, where they formed by cavity filling during shearing. The gold is concentrated in fractures within the

Zn, and Mo (Singer and others, 1978). The area contains claims for copper and gold in quadrangle as having potential for base and precious metal vein deposits, which have low tonnage but locally may have high grades. In the Chickaloon River (areas labeled 5C), placer-mining was reported in the early 1900's, but mine locations are unknown. The mines were thought to be in the northern part of the drainage, perhaps north of the Anchorage quadrangle (Cobb, 1979). Two gold-bearing, heavy-mineral-concentrate samples were collected in the northern part of the Chickaloon River. One is along the northern quadrangle boundary. Felsic volcanic rocks north of the Anchorage quadrangle host copper and gold occurrences (Singer and others, 1978), as described above, and could be the source of the gold. Gold also was reported from the southern part of the river, near the mouth of Boulder Creek. Only three out of twenty USGS heavy-mineral-concentrate samples collected from the

Chickaloon River and its tributaries were enriched in Au (and Ag). One of these samples was collected from a western tributary to the Chickaloon River, near Cobb's (1979) placer prospect at the mouth of Boulder Creek (the southwestern part of area 5B). The local bedrock in this area is the Chickaloon Formation and an Eocene mafic intrusion The remaining seven areas labeled 5 were delineated by ridgetops separating drainage basins containing only one gold-bearing sample (except for the easternmost area, which contains two gold-bearing samples). The areas expose Cretaceous and Tertiary sedimentary rocks, the Upper Triassic(?) and Lower Jurassic Talkeetna Formation (in the easternmost of the seven areas), and hypabyssal felsic and intermediate

intrusions of Eocene age. The Talkeetna Formation is a potential source of gold. Volcanic rocks of the Talkeetna Formation host numerous stratiform and stratabound zones of pyrite, slightly enriched in Ag, which are restricted to intermediate to silicic volcanic rocks (Newberry, 1986). Sparse quartz veinlets contain bornite, chalcopyrite, epidote, and supergene chalcocite and covellite; locally these veinlets assay very high in Cu, Ag, and Au

The Paleocene and Eocene Chickaloon Formation, in the Matanuska Valley, includes a lower part consisting of conglomerate and lithic sandstone derived mostly from local erosion of the Talkeetna Formation (Winkler, 1978). This lower part of the Chickaloon Formation could have contributed gold from paleoplacers in the conglomerate, originally derived from the Talkeetna Formation, to present stream sediment in the quadrangle. The small Eocene stocks, dikes, and sills of rhyolite, quartz latite, latite, and dacite intrude rocks as young as the basal part of the Paleocene to Miocene(?) volcanic rock unit, in the northern part of the quadrangle. Where these stocks, dikes, and sills intrude the Talkeetna, Matanuska, and Chickaloon Formations (and other units), hydrothermal mineralizing systems could have developed. For example, studies of precious-metal deposits suggest that hydrothermal activity, involving alteration and mineralization, occurs during the later stages of volcanic activity within a volcanic cycle (Silberman,

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